Characterization of Wavelength Selective Photonic Switches for Scalable Data Center

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Microsoft tests underwater data center

• In 2014, data centers in USA consumed 70 billion kWh ~2% of total energy!¹

Photonics

• Secure communication
• Faster data processing
• Energy efficient!

Wavelength Division Multiplexing

On-Chip Optical Switching

- Signals are combined (MUX) into one fiber
- Signals are re-routed from one channel to another and separated out (DEMUX)
- This process can be scaled down with integrated photonics
Wavelength Selective Switch

- Resonant wavelengths are thermally tuned
- One signal can be **added** to the same path of another signal
- Input signal can also be **dropped** off to another path

Second Order Microring Resonator
Integrated Photonics Switch Design

- Electrical-Pads
- Optical-Switches
- Optical-Edge Couplers
- Fabricated through the AIM Photonics foundry
Coupling to Channels

- 4 Output channels
- 4 Input channels
1. Maximizing the Transfer Function of Switches

- Transfer function is measured from the drop port
- Goal is to maximize coupling into 2 sets of second order rings
- Create 3.2 nm separation between resonant peak
- Working in the telecommunication wavelength (C-band: 1530 nm – 1565 nm)
2. Bit Error Rate Test

- Distinguishable lines: Low noise and jitter
- Symmetric open eye: wide bandwidth and high signal

![Eye Diagram](image)

- Modulated signal is sent at the resonant wavelength of one pair of rings
- Inability to distinguish signal correctly generates errors
- Known bits of signal is compared with to determine number of errors

- Distinguishable lines: Low noise and jitter
- Symmetric open eye: wide bandwidth and high signal
3. Switching (Rise/Fall) Time

- Heat/Energy takes time to transfer
- Electrical signal is obtained through oscilloscope

**Diagram**

- DAC sends on/off signal
- Tunable Laser
- Device Under Test
- Optical → Electrical Signal Converter
- DAC tunes ring resonance to let light pass/not pass
Ports Under Test

Port Sets:

• IO 1 = Input 1 & output 2
• IO 2 = Input 3 & output 3
• IO 3 = Input 4 & output 4
Transfer Function

![Graph showing transmission vs. wavelength with different curves labeled IO 1, IO 2, IO 3.]
Bit Error Rate Test

BER vs Optical Attenuation

Log10(BER)

Attenuation [dBm]

IO 1
IO 2
IO 3
Switching Time Oscilloscope

- Switching time is shown for a thermal tuner in IO 1
- Time axis includes negative value because oscilloscope set t=0 when triggered
Switching Time

\[ T_{\text{rise}} = 1.8 \times V - 2.9 \]
\[ R^2 = 0.9534 \]

\[ T_{\text{fall}} = 0.3 \times V + 0.12 \]
\[ R^2 = 0.9184 \]
Conclusion

• Able to simultaneously switch 2 wavelengths and separate local maxima by 3.2 nm to reduce optical cross talk

• BER test demonstrates a low error rate of $10^9$ for IO1 @ 15 dBm optical attenuation but needs to be repeated

• Coupling decreases with increasing I/O #, resulting in lower signal to noise ratio (SNR)

• Eye diagram show high noise and jitter but wide bandwidth

• Optical power is reduced by >50% at 4 V difference, which requires less than 5 us switching time
Future Work

• BER test needs to be repeated for all the I/O
• Repeat the above experiments with a fiber array
• Reduce noise and measure optical crosstalk
• Decrease switching time with a material that allows electro-optic tuning (i.e. lithium niobate) or through carrier depletion
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